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## THE PLANT AS MACHINE.

*Plant Response as a Means of Physiological Investigation.* By Prof. Jagadis Chunder Bose. Pp. xxxviii+781; with 278 illustrations. (London: Longmans, Green and Co., 1906.)

THE emotions that will be aroused by this book in different classes of readers may well be very dissimilar. A biologically equipped reader with no special knowledge of plant physiology will experience dazzled admiration for the logical, progressive way in which the author builds up, not in words, but actually experiment on experiment, a complete functioning plant from three simple conceptions. These conceptions, which will be critically considered later, are briefly the following:—*stimulation*, the transference of external energy to the plant; *contraction*, the constant "direct response" of plant-cells to stimulation; *expansion, including growth*, the "indirect response" to stimulation.

This present book, big as it is, is devoted almost entirely to the mechanical responses of plants; another volume is promised on electrical responses. By mechanical responses we are to understand all movements, in the widest sense, not only the obvious movements of sensitive and sleeping plants with all geotropic and heliotropic movements, but also the movements of expansion in growth and the pumping of water up the plant, and, further, "death-spasms" and all the minute shrinkages of unspecialised cells produced by stimulation. All these vital manifestations are dealt with in sequence, passing from the simple to the complex, and in them the author finds nothing that cannot be interpreted in terms of his three primary conceptions.

Another type of reader, a student of plant physiology, who has some acquaintance with the main classical ideas of his subject, will feel at first extreme bewilderment as he peruses this book. It proceeds so smoothly and logically, and yet it does not start from any place in the existing *corpus* of knowledge, and never attaches itself to it with any firm adherence. This effect of detachment is heightened by the complete absence of precise references to the work of other investigators. The student, puzzled by the number of original conceptions, may hesitate between accepting and rejecting the whole book, and will probably wait, with judgment suspended, until someone with more conventional ideas of the plant than Dr. Rose has re-investigated the phenomena and interpretations here brought forward.

The extreme isolation of this book is no doubt to be explained by the author's scientific past. Dr. Bose was, we believe, a physicist originally, and has been drawn into biology by following up the similarities which he has announced between the electrical and other responses to stimulation given by metal bars and by living animal or vegetable cells (see "Response in the Living and Non-Living," 1902). Dr. Bose preaches the continuity of response in all matter, living or non-living, in metal wires, muscle fibres, sensitive plants, and vegetable cells in general, and has described effects in metals corresponding to fatigue, latent period, summation of stimuli, temperature-optima, and other characteristic vital phenomena. From this similarity of the effects of stimulation he passes to assuming a similarity of mechanism in all these cases. In metal bars the mechanism is, of course, physical, and there is no question of stored chemical potential energy liberated on stimulation: this purely physical interpretation is by him extended to living cells; molecular change of protoplasm, not chemical change, is all he recognises, and when a temporary storing of energy has to be admitted he considers it a purely physical accomplishment.

The originality of this and of other fundamental views stated or implied in this book makes it more important for a reviewer to consider these conceptions critically than to give an outline sketch of the whole book, interesting and stimulating though it is.

Dr. Bose conceives the living organism as a delicate responding physical machine the responsive movements of which are brought about entirely by external stimuli. All external stimuli, chemical, thermal, mechanical, photic, &c., produce the same *direct response*, namely, contraction of the cells with active expulsion of water, a negative turgidity-variation, and a negative electrical variation.

These effects are observable, not only in so-called "sensitive" plants, but in all living parts of plants, and it is a definite advance, due to Dr. Bose's delicate experimentation, to have it shown that all radial organs, stems, styles, stamens, &c., shorten on stimulation.

In addition to the direct response of contraction there is also an opposite effect, the so-called indirect response of expansion, which is produced at a distance from the stimulus by the water expelled in contraction causing distension or expansion of cells elsewhere, with accompanying positive turgidity-variation and positive electrical variation. Of this nature, an indirect effect of stimulation merely, is the characteristic vital phenomenon, growth.

Much, then, is made to depend upon stimulation, yet the author holds the astonishing view that all the work done by the plant is the real equivalent of energy received by the impact of stimuli from without. The author does not even attempt to impart verisimilitude to this view by including food materials among his stimuli. For him the living organism is not a combustion engine doing work by the energy liberated chemically in oxidising carbon compounds, but it is just such a physical machine as a windmill, requiring blows rather than food to make it work, and the last picture in the book is indeed a figure of this windmill. We fear that, valiant and thorough as Don Quixote in his attack upon this misconceived phenomenon, the author hardly avoids a similar fate by starting with an inverse misconception.

It is easy to see that Dr. Bose acquired this view of stimulation originally from his experiments on the responses given by metal bars. In these experiments the work done on the bar, generally by torsion, greatly exceeded the output of energy in the electrical and other response produced. There is no liberation of stored potential energy in such a case, therefore there is really no similarity with the mechanism of the living cell, though molecular change no doubt occurs in the protoplasm as it does in the metal wire.

Just as we hold that Dr. Bose has transferred from his physical experiments a conception of biological stimulation which is inadmissible for either animal or vegetable cells, so it seems to us that his conception of contraction is derived only from the activity of animal muscles, and is inadmissible for the mechanical response of plant cells. There is really no evidence that these two phenomena are of quite the same order and both due to active contraction of the living part of the cell, though an *a priori* philosophical outlook has led many to assume it.

When the irritable stamens of Centaurea are touched they shorten, even to one-third of their length, which diminution is accompanied by an extrusion of a corresponding amount of cell sap from the cells into the intercellular spaces, and by comparative flaccidity of the cells.

Now the vegetable cell, unlike the muscle cell, is at its maximum rigidity when at rest, being distended by the osmotic force of molecules dissolved in its sap. These molecules are kept in by the protoplasmic lining of the cell, which is impermeable by them though freely permeable by water. The tenacious and elastic cell-wall, itself freely permeable to everything, is able, owing to its tenacity, to protect the protoplasm from being ruptured by the osmotic pressure, which reaches several atmospheres.

Whether one holds the view that the shrinkage which occurs on stimulation has, as its antecedent stage, decomposition of some of the osmotic molecules, or sudden permeability of the protoplasm, the contraction itself cannot be attributed to active contraction of the living part, but must be due to the forceful elastic contractile recovery of the dead cell-wall, now no longer distended through osmotic force. It is incredible that the stimulated protoplasm, so watery in texture, can contract actively against an extending force of several atmospheres and actively expel cell-sap. Unlike muscle, the "contracted" plant cell is flaccid, and the protoplast does its mechanical work while recovering from contraction, in again extending its wall ready to react to fresh stimulation. This corresponds to the relaxation time of a muscle, so that the two machines are quite different in their phases.

Further, another fundamental difference lies in this, that a muscle does not really contract in volume when stimulated; it merely alters its shape, becoming shorter and broader, a special property exhibited by a number of non-living peculiarly organised structures, india-rubber strips, for example. The plant cell, on the contrary, really contracts in volume; whether it alters its shape depends upon the relative extensibility of the different walls. Again, this contractility of plant cells is inherent in the very organisation of the cell, and is found in all primitive types and in all young cells, and is not a specially evolved mechanism like the contracting muscle fibre. It is finally interesting to note that it has not been really proved that heat production is associated with the contraction of plant cells rather than with the subsequent expansion when work has to be done by the protoplast.

Dr. Bose's conception of growth is more elusive and still more isolated. Growth, the indirect remote response to stimulation, is due to that part of the energy of a stimulus not used in direct response. This energy is held to be communicated hydraulically to the growing point as pulsations, and of these pulsations graphic records are given. Stimuli applied directly to the growing region must, of course, cause contraction, *i.e.* retardation of growth, as their direct response; therefore the pulsations of the growing point are attributed, as indirect responses, mainly to excitatory reactions occurring below the zone of growth.

Dr. Bose's book abounds in experimental evidence on all points, a feature of the greatest merit, yet we must say that many of the fundamental experiments are not nearly critical enough. For example, one reads continually of the striking effect of *thermal* stimuli: these are produced by the electric heating of a platinum-wire-frame which surrounds the living stem; when a succession of stimuli is wanted it is produced by passing and cutting off the current alternately. In relation to this treatment we are given no idea of the temperature that the wire or the plant attains, or of how far the temperature of the plant actually oscillates under this alternately hot and cold environment. The effects produced in this way are very extraordinary—longitudinal contraction of stems, styles, and other radial organs, stimulation of *Mimosa* pulvini, &c.—but there is no attempt to trace the transition from such effects to those of surrounding high temperatures which are kept uniform.

The reader rather distrusts the author's views on thermal effects on finding him propose seriously to examine (chapter xliv.) the effect upon growing parts of "thermal radiation" apart from the effect of the actual temperature of the part. This distinction is surely confusion of thought, and the differences recorded are no doubt due to actual difference of temperature, for the method of experiment is quite fallacious. It is, indeed, supposed that a plant surrounded with a hot radiating platinum spiral, the whole being enclosed in an experimental chamber, will be at the same temperature when there is a heat-proof screen between the plant and the radiating spiral and when this is removed, and this just because a thermometer somewhere in the general air of the chamber keeps a uniform constant temperature all the time!

The apparatus and the experimental methods employed show great ingenuity and a praiseworthy simple directness of attack which, however, occasionally passes into *naïveté*. One feels that valuable results are to be got with the delicate optical lever, the kunchangraph, the balanced crescograph, the morograph, &c., instruments which measure changes of one-hundredth of an inch or less, though their very delicacy must introduce sources of error, about which nothing is to be found in the book. Workers on growth will be forced to abandon their primitive and clumsy methods, and much good will result from the refinements here introduced.

In conclusion, we can only say that there are literally scores of special points of the greatest interest raised in the course of this book, which cannot, of course, be dealt with here. If the primary desire that these points raise is the desire to cross-examine, it is to cross-examine, not the author, but the plant itself which bears such uniform and honestly-intentioned testimony in favour of Dr. Bose's views. All such experimental cross-examination will make for the progress of knowledge, and we think that Dr. Bose can claim that his book will be an external stimulus (if not in his sense at least in ours) to the growth of plant physiology and the responses of future investigators.

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## *THE NORSEMEN IN THE ORKNEYS.*

*Monumenta Orcadica. The Norsemen in the Orkneys and the Monuments they have left.* By L. Dietrichson. With original drawings and some chapters on St. Magnus Cathedral, Kirkwall, by Johan Meyer. Pp. xiv+200. (Kristiania; London: Williams and Norgate, 1906.) Price 3*l.* net.

THIS handsome quarto volume from the pen of the learned head of the Art Museum of Christiania is issued in a bi-lingual form, being divided into two parts; the first is an abridgment in English of the second, which is in Norwegian. It appears at an opportune time, when the ties connecting the two kingdoms are closer than they have ever been since the separation of the islands with which it deals from the Scandinavian kingdom on the marriage of the daughter of Christian I. to the Scottish king in 1469.

Based chiefly upon the importance of the Orkney Islands to Norway as a basis in the Middle Ages, and on the historical interest attaching to the architectural remains of the centuries during which they were ruled from that country, the author's task has been a scientific inquiry into every detail connected therewith. He displays throughout a most intimate knowledge, not only of the Sagas, but of the writings of those authors on both sides of the German Ocean who have essayed to identify the sites and fix the questions of the dates and details of construction of the more important erections; and during a visit to the islands half a dozen years ago, when he was accompanied by Mr. Myers, he had an opportunity of personal inspection of the remains, and has produced a work that will be heartily welcomed by all students of the archæology, history, and architecture of our northern isles.

The introduction deals with the Orkneys and their connection with Norway, and with the Orkneys in literature, in which the author, after enumerating all the islands and parishes with their Norse derivatives, adjusts a few of them according to his own researches, describes their scenery, climate, and natural history, and gives a list of many Norse words surviving in the names of homesteads and in the dialect; the Roman, Norse, and Scottish authors whose writings have constituted the sources of the history of the islands are also briefly referred to. In order to present the work as a continuous whole, the author has included the pre- and post-Norwegian periods, and divided it into three books, dealing respectively with the prehistoric, the Norwegian, and the Scottish remains. He is in full accord with all other Norse scholars in repudiating the idea of a Scandinavian origin for the sepulchral chambers, stone circles, standing stones, and brochs which abound all over the islands; these he briefly describes, without, however, committing himself to any of the various theories that have been urged regarding them, and relegates them all to a period anterior to A.D. 600.

From that period to A.D. 872 is assigned to an early Celtic Christian occupancy, that of the Peti and Papæ. The distinguishing architectural features of their chapels are pointed out, six existing ruins are enumerated, while from saintly dedications and Saga records the sites of eight additional ones that have disappeared have been identified.

The Norse period 872 to 1468 is the most important and interesting portion of the work; there is already a large amount of literature dealing with this period, and to those who have been nurtured on the contributions of Munch, Dryden, Anderson and others there may be much of detail to unlearn by those who accept the author's views. At the same time, the older works suffer nothing by the comparison; in fact, any faithful interpretation or correlation of facts, both historical and monumental, could hardly have been looked for until after the publication of the Rolls edition of the Icelandic Sagas in 1887. Prof. Dietrichson opens it with a wave of emigration from Norway to the island of Sanday, where he supposes the first stronghold of the earls to have been established. The monuments are chronologically arranged; the first group comprises the remains assigned by the author up to the end of the tenth century, and embraces the tumuli bearing the names of the Saga characters who are recorded as having met their death in the Orkneys and as far south as the Oykell in Sutherland, the Norse burial mounds being distinguished from the Celtic "cairns" by their having been constructed, not of stones, but of earth "barrows," as well as a few churches and the Norse earls' palace as Birsay.

With the eleventh century the interest increases; among the more important items which are new may be mentioned the confirmation of the opinion that the Thing-stead was held in Rendall, in opposition to the popular belief that it was at Stenness. The question of the time of the erection of the unique St. Magnus Church on Egilshay, which has been a puzzle to antiquaries for a long time, has been focussed for various assigned reasons into the three years immediately following the murder of the earl on that island, that is, 1135–8.

Ecclesiologists who have been searching for the